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MARTIAN DUST THRESHOLD MEASUREMENTS - SIMULATIONS UNDER HEATED SURFACE CONDITIONS

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Diurnal changes in solar radiation on Mars set up a cycle of cooling and heating of the planetary boundary layer, this effect strongly influences the wind field. The stratification of the air layer is stable in early morning since the ground is cooler than the air above it. When the ground is heated and becomes warmer than the air its heat is transferred (by molecular conduction action - no flow at the ground) to the air above it. The heated parcels of air near the surface will, in effect, increase the near surface wind speed or increase the aeolian surface stress the wind has upon the surface when compared to an unheated or cooled surface.

This means that for the same wind speed at a fixed height above the surface, ground-level shear stress will be greater for the heated surface (unstable case) than an unheated surface. Thus, it is possible to obtain saltation threshold conditions at lower mean wind speeds when the surface is heated. Even though the mean wind speed is less when the surface is heated, the surface shear stress required to initiate particle movement remains the same in both cases.

To investigate this phenomenon, low-density surface dust aeolian threshold measurements have been made in the MARSWIT wind tunnel located at NASA Ames Research Center, Moffett Field, California. The MARSWIT is an open circuit wind tunnel that is operated within a large pressure chamber (4000 m^3) that allows a range in operating pressure from a few millibar to one atmosphere of pressure (Greeley et al., 1977). The current experiments were carried out with both heated and unheated surface temperature conditions. The heated surface condition represents or models diurnal surface heating by radiation from the sun. The unheated surface represents a neutrally stable condition. The heating of the floor primarily affects the vertical turbulent structure of the boundary layer. The exact level of heating is unknown under Mars surface conditions; however, it is expected to produce a maximum temperature difference of 25 K between the surface and the atmosphere above it. (Hess et al. 1977; Ryan and Henry, 1979).

Limited vertical temperature profiles also were measured under several heating conditions which enabled a determination of friction speed, u_* as a function of freestream speed at a specified heating condition. Additionally, the surface material temperature was measured with a thermocouple from which the value of bulk Richardson number was determined.

On Mars, from the Viking Landers, there are no direct data available as to the mean wind speed and surface temperature when the initial dust movement occurred. However, Arvidson, et al. (1983) estimate that winds of 25 to 30 m/s would be needed to initiate particle motion of optimum sized surface material (i.e., about 100 microns in mean diameter). Presumably this would occur at Mars noon when the temperature difference between the surface and Lander was a maximum. For the Lander case this corresponds to a bulk Richardson number of about -0.02 at threshold.

The experiments were carried out for two different sized particles, one having a mean diameter of about 105 microns while the other sample material had a mean diameter of about 11 microns. Threshold measurements were made under two surface temperature conditions: one where the surface was not heated (i.e., uniform temperature throughout the boundary layer profile) and the other where the surface was heated. The amount of surface heating was varied for each experiment and approximately represents a value of bulk Richardson number from zero to -0.02 which is believed to be in the range that exist on the surface of Mars near the Viking Lander sites.

The first series of tests examined threshold values of the 100 micron sand material. At 13 mb surface pressure the unheated surface had a threshold friction speed of 2.93 m/s (and approximately corresponded to a velocity of 41.4 m/s at a height of 1 meter) while the heated surface, equivalent bulk Richardson number of -0.02, yielded a threshold friction speed of 2.67 m/s (and approximately corresponded to a velocity of 38.0 m/s at a height of 1 meter). This change represents an 8.8% decrease in threshold conditions for the heated case. The values of velocities are well within the threshold range as observed by Arvidson et al., 1983. Figure 1 presents this data. As the surface was heated the threshold speed decreased. At a value of bulk Richardson number equal to - 0.02 the threshold friction speed and threshold wind speed appeared to level-off to a constant value.

This trend also was observed in the MARSWIT experiments involving the 11 micron sized-silt material. Although we were not able to directly measure extensive numerical values to support this trend, it was readily observed in the tunnel testing. Note, it is extremely difficult to maintain constant ambient chamber pressure while continuously increasing the wind flow through the tunnel. Figure 2 does, however, present the two data points that have been measured to date. The threshold friction speed at 6.7 mb pressure of the 11 micron dust material was found to be 9.4 m/s with the unheated surface. When the surface was heated to a value of bulk Richardson number equal to -0.01, the friction threshold speed was reduced by 18% to a value of 7.7 m/s. Unfortunately, this is the only ambient chamber pressure (6.7 mb) that the MARSWIT was able to achieve threshold conditions.

The data results suggest that as the surface is heated the threshold wind speed will decrease. The amount reduction in threshold wind speed appears to be a function of bulk Richardson number as well as the mean size of the test material. The smaller sized materials will tend to experience more of a reduction in threshold wind speed. It is anticipated that for larger size particles there will be negligible difference between heated and unheated surfaces (larger than 1 mm in diameter) in values of threshold wind speed.

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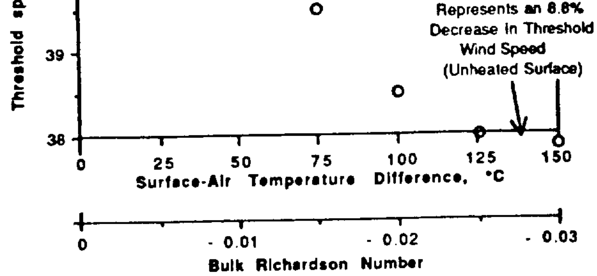

Figure 1. Threshold wind speeds and Bulk Richardson Numbers for 100 micron diameter Quartz sand.

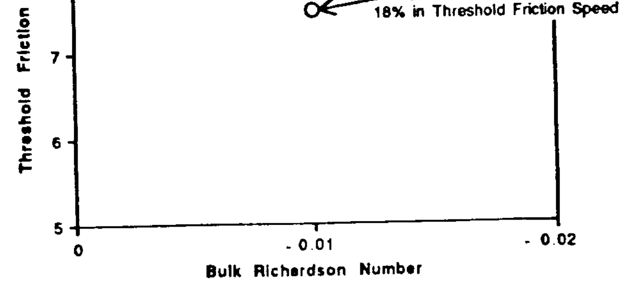

Figure 2. Threshold Friction Speeds for 10 micron diameter silt.